INTELLIGENT SYSTEMS MEMORY STRUCTURING

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Abstract: The requirements for the memory structuring of intelligent systems are discussed. Simultaneously with the introduction of information into memory there should take place the processes of association links (bonds) formation, hierarchy systematizing, classification and concept formation. The growing pyramidal networks (GPN) meet these requirements. Many years of experience of GPN application for data analyses in chemistry and material studies proves their sufficiently high potential.

Keywords: intelligent systems, growing pyramidal networks, data analysis.

1. Perception, presentation and analysis of information in intelligent systems

1.1. Competition of a computer with a man in resolving of intelligent problems more and more often ends up in the victory of a computer. But there arises the evident contradiction: computer genius victoriously solves the most complicated multivariate problems in artificial, relatively poor media (chess, for example) and “stumbles” over solving simple (for a man) life problems, requiring still quick understanding and assessment of multi-component situation.

What compensates the evident advantage of a computer over a man in quickness? The answer is unanimous that the reason lies mainly in memory structure. We will try to identify the structural peculiarities of memory, which, to our mind, are necessary for formation of clear explanations of a human phenomenon of information processing.

1.2. The peculiarity of intelligent systems, which causes no doubts, is the ability to analyze the perceived information. The process of analysis consists in picking up the integral parts and characteristic attributes of the analyzed whole. The product of analysis is organized (for example, with the help of logic links) sum of object attributes.

Thus, irrespective of the type of the information perceived (continuous or discrete) at a certain stage of analysis there appears a discrete representation of objects in the form of arranged aggregate of information blocks – attributes. The attributes serve as building blocks for the following analytical processes, leading in the long run, towards formation of generalized information models of the objects perceived. So, discretization of the perceived information, which consists in demonstrating attributes of objects, is an important peculiarity of intelligent systems.

1.3. The prevailing tendency in developing of intelligent systems is the improvement of man – machine interaction until the achievement of partner level of man-machine relations. That is why it is important to use natural, pertaining to a man principles of problems, situations and media modeling in computers. Partner model types (a man and a computer) should be similar. In life activity of a man a very important role is played by logic - linguistic information models, i.e. such models where the main elements are not numbers and calculations but names and logical bonds. Logic - linguistic models are adequately described with natural language constructions, and it is one of their decisive merits for designing of a man – machine interface. In computers to come there should be created conditions for man – machine solving of problems in partner mode providing switching over from a computer to a man and vice versa within the process of solving of problem. Such mode could be set up only by means of adjustment of information model types, used by partners. Logic – linguistic models are the most acceptable model types for such an adjustment.

1.4. Formation of memory structure is done simultaneously with perception of information and under the impact of the information perceived and already stocked. The memory structure reflects the information perceived. Information structuring is an indispensable function of memory.

The main processes of structuring include formation of associative links by means of identifying the intersections of attributive representations of objects, hierarchic regulation, classification, forming up generalized logical attributive models of classes, i.e. concepts.

Under real conditions of information perception there is often no possibility to get whole information about an object at once (for example, because of faulty foreshortening or lighting during the reception of visual information). That is why the processes of memory formation should allow for the possibility of “portioned” construction of objects models and class models by parts.

1.5. In different processes of information processing objects are represented by one of the two means: by a name (convergent representation) or by a set of meanings of attributes (displayed representation). The structure of memory should provide convenient transition from one representation to another. Mechanisms, providing such transition in neuro system of a man at recognition or recollection are considered in the works of S.G. Voronkov and Z.L.Rabinovich [1].

Let us sum up the above mentioned theses in the form of requirements to memory structuring in intelligent systems.

- In intelligent systems knowledge of different types should be united into net-like structure, designed according to principles common for all types of knowledge.
- The network should reflect hierarchic character of real media and in this connection should be convenient for representation of gender-type bonds and structures of composite objects.
- Obligatory functions of the memory should be formation of association bonds by revealing intersections of attributive object representations, hierarchic structuring, classification, concept formation.
- Within the network there should be provided a two-way transition between convergent and displayed presentations of objects.

2. Growing Pyramidal Network

The above mentioned requirements are met by growing pyramidal network. The theory and practical application of growing pyramidal networks are represented in many publications [2-5]. In this paper we present somewhat changed rules of formation of growing pyramidal network, ensuring their construction at the introduction of object attributive descriptions by parts. The example of a growing pyramidal network is presented in Fig.1.

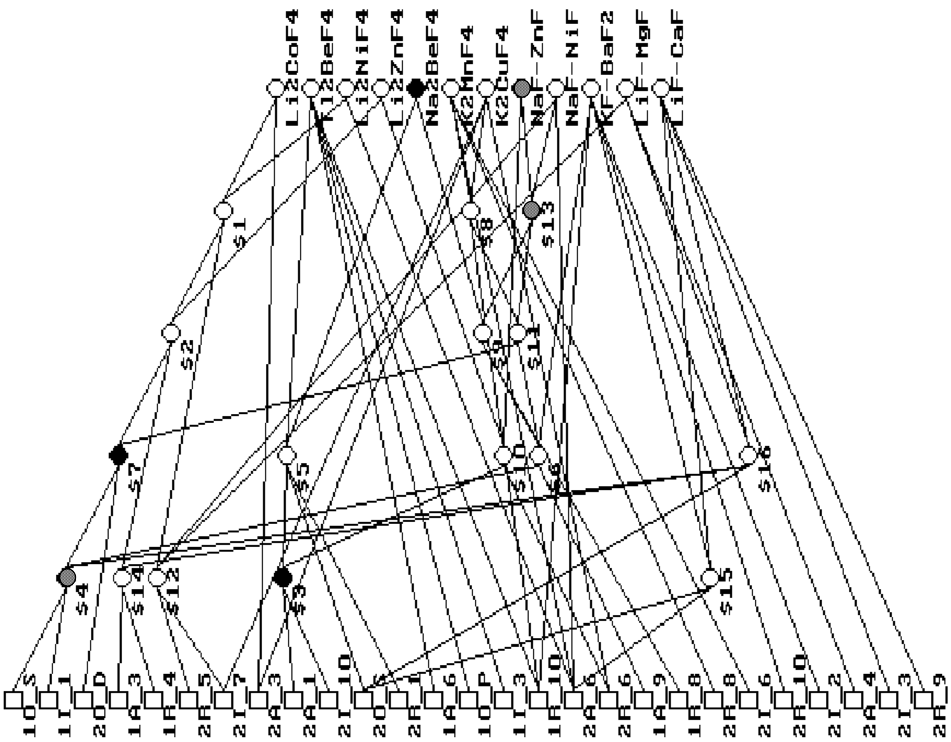

Fig. 1.

The pyramidal network is called a cycled oriented graph, where there are no vertices having one incoming arch. The vertices that have no incoming arch are called *receptors,* other vertices are called *conceptors*. The subgraph of the pyramidal network which includes *a* vertex and all vertices, from which there are paths to *a* vertex, is called *pyramid* of *a* vertex. The vertices pertaining to *a* vertex pyramid form up its *subset*. The set of vertices towards which there are paths from *a* vertex is called *superset*.

In a subset and a superset of a vertex there are 0-subset and 0-superset that consist of those vertices that are immediately connected with it. While constructing a network the sets of meanings describing some objects (materials, aggregate states, situations, illnesses etc.) serve as incoming information. Receptors correspond to the meanings of attributes. In different problems they could be names of properties, relationships, states, actions, objects and objects classes. Conceptors correspond to the descriptions of objects as a whole and intersections of descriptions. The network shown in the Fig.1 is built on the basis of the Table where the objects are pairs of chemical elements, forming and not forming compounds.

Table

Object	Class	1O	1A	1R	1I	2O	2A	2R	2I
Li2CoF4	A	S	3	4	1	D	3	5	7
Ti2BeF4	A	P	6	10	3	S	1	1	10
Li2NiF4	A	S	3	4	1	D	6	5	7
Li2ZnF4	A	S	3	4	1	D	1	6	10
Na2BeF4	A	S	9	8	1	S	1	1	10
K2MnF4	A	S	9	10	1	D	6	8	6
K2CuF4	A	S	9	10	1	D	3	6	7
NaF-ZnF2	B	S	9	8	1	D	1	6	10
NaF-NiF2	B	S	9	8	1	D	6	5	7
KF-BaF2	B	S	9	10	1	S	6	10	2
LiF-MgF2	B	S	3	4	1	S	4	5	7
LiF-CaF2	B	S	3	4	1	S	6	9	3

In the Table he object descriptions are given, where 1O, 1A, 1R, 1I are the names of attributes, describing the first element of the compound; 2O, 2A, 2R, 2I are the names of attributes, describing the second element of the compound, and the letters and figures in cells are the meanings of the corresponding attributes.

In the initial state the network consists only of receptors. Conceptors are formed as a result of the work of algorithm of network construction. The algorithm described in a number of publications [2-5] is meant for the work in situations, where the attributive description of each object is fully known and is introduced as a whole. With appearing of new attributes, which characterize the object, it is necessary to form a new complete description of the object and to replace the pyramid that represents it with another one, which corresponds to the new description. But as it was mentioned in real situations of functioning of an intelligent agent simultaneous perception of all characteristics of an object is far from possible. In such cases the information about objects comes in parts. Then there arises the necessity to change a bit the algorithm of constructing a network to provide the possibility to include into the existing object pyramids new attributes according to their appearance without replacement of pyramids as a whole. Now we will present the description of the changed algorithm.

At the introduction of an attributive description of an object receptors corresponding to the meanings of attributes coming into the description are transferred into the state of *excitation*.

The excitation is propagated through the network. The conceptor is switched to the state of excitation if all vertices of its 0-subset are excited. Receptors and conceptors preserve the state of excitation within the period of performing all the operations of constructing of the network.

Let at the introduction of the description of some object F_a be the subset of the excited vertices of 0-subset of *a*- vertex; *G* is the set of the excited vertices of the network having no other excited vertices in their supersets.

Introduction of new vertices and arcs is done according to the following rules.

Rule 1.

If *a* vertex is not excited and F_a set contains more than one element, then arcs, connecting vertices from F_a set with *a* vertex are annulled and a new conceptor is introduced, which is connected by incoming arcs with vertices of F_a set and by an outcoming arc with *a* vertex. The new vertex is in the state of excitation.

Fulfillment of the rule 1 is illustrated by Fig.2(I, II). The network II appears after excitation in the network I of 2,3,4,5 receptors. As it follows from the rule 1, the condition of introduction of a new vertex into the network is the situation when a certain vertex is not completely excited (not all vertices but not less than two of its 0-subset are excited). New vertices are introduced into 0-subsets of not completely excited vertices.

After introduction of new vertices into all areas where the condition 1 is met, the rules 2 or 3 are applied.

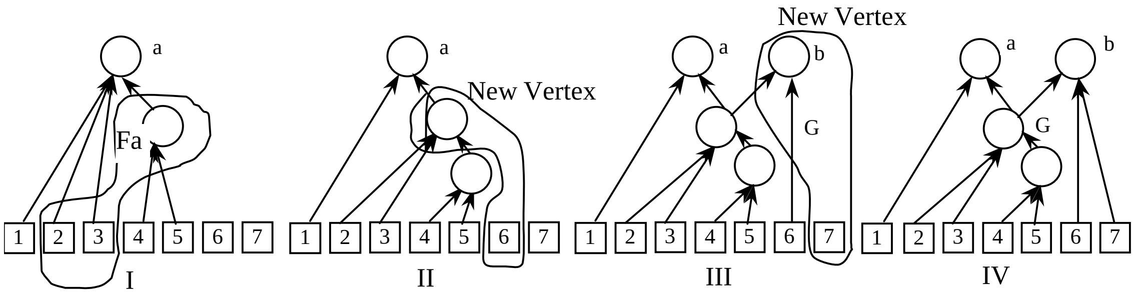

Fig. 2.

Rule 2.

If *G* set contains more than one element and does not include the vertex marked with the name of the object introduced, a new conceptor joins the network and is connected by incoming arcs with all vertices of *G* set. The new vertex is in the state of excitation.

Fulfillment of the rule 2 is illustrated in Fig.2 (II, III). The network III appears after excitation of receptors 2, 3, 4, 5, 6 in the network II.

Rule 3.

If *G* set contains the vertex, marked with the name of the object introduced, this vertex is connected by incoming arcs with other vertices of *G* set.

Fulfillment of the rule 3 is illustrated in Fig.2 (III, IV). The network IV appears after excitation of receptors 2, 3, 4, 5, 6, 7 in the network III under condition that this set of receptors corresponds to the description of *b* object.

In the changed algorithm the possibility of introduction of new attributes into the existing pyramids is provided by the rule 3.

Pyramidal networks are convenient for performing different operations of associative search. For example, one could choose all objects, containing a given combination of attribute meanings, following the paths coming out the vertex, which corresponds to this combination. For the access of all objects the descriptions of which intercross with the description of the given object, it is enough to trace the paths coming out of the vertices which form up its pyramid. All processes, connected with construction of the network at the processing of one description are localized in a relatively small part of the network, i.e. in the pyramid, corresponding to this description.

Hierarchical structure of the networks, which allows them to reflect the structure of composing objects and gender-species bonds naturally, is an important property of pyramidal networks.

Conceptors of the network correspond to the combinations of attribute meanings, defining conjunctive classes of objects. With insertion of excited vertices into the pyramid of the object there takes place linking of the object with the classes, the definitions of which are represented by these vertices. Thus, while building a network, there form up conjunctive classes of objects, i.e. classification without a teacher takes place. Classifying properties of a pyramidal network are very important for automation of media and situation modeling.

The transfer from convergent representations of objects (conceptors) to displayed ones (sets of receptors) is fulfilled by a survey of pyramids in different directions.

In growing pyramidal networks there are realized the processes of forming generalized logical models of object classes, i.e. concepts.

The formed up concept of any complexity is represented in the network by an ensemble of specially picked out vertices. On the basis of network analysis a special procedure builds up a concept in the form of a logical expression.

Logical expressions defining classes of objects are united in Cluster Data Base (CDB). CDB contained information about object groups (clusters) that are specific for the domain under investigation. CDB are used for classification, diagnostics and prognostication.

When the concept for a certain class is formed, the problems of forecasting and diagnostics are reduced to the problem of classification. Classification of new objects is done by comparing their attributive descriptions with the concept, determining the class of objects to be forecasted or diagnosed. The objects could be classified calculating the meaning of logical expressions, representing the corresponding concepts.

In a pyramidal network the information is stocked by its reflection in the network structure. Information about objects and object classes is represented by ensembles of (pyramid) vertices, distributed along the whole network. Introduction of new information causes redistribution of bonds between the vertices of the network, i.e. change of its structure.

Of course, the benefits of pyramid networks are fully demonstrated with their physical realization, which allows parallel spreading of signals through the network.

There is the analogy between the main processes taking place in growing pyramidal networks and neuron networks. The decisive advantage of a growing pyramidal network is the fact that its structure is formed completely automatically depending on the introduced data. As a result there is achieved optimization of information presentation due to adaptation of the network structure to the structural peculiarities of the data. Unlike neuron networks the adaptation effect is achieved without introduction of a priori excess of the network. The learning process does not depend on predetermined network configuration. The drawback of neuron networks if compared to the growing pyramidal network is also the fact that generalized knowledge in them cannot be represented in the form of rules or logical expressions. It makes their interpretation and understanding by a man difficult.

The program system CONFOR (CONcept FORmation) that implements methods of data analysis on the basis of growing pyramid networks has been tested by time. The typical applied problems, for solving of which this system was used are: forecasting new chemical compounds and materials with the indicated properties, forecasting in genetics, geology, medical and technical diagnostics, forecasting malfunction of complex machines and sun activity.

3.Summary

Pyramidal network is a network memory, automatically tuned into the structure of incoming information. Unlike the neuron networks, the adaptation effect is attained without introduction of a priori network excess.

The research done on complex data of great scope showed high effectiveness of application of growing pyramidal networks for solving analytical problems. Such qualities as simplicity of change introduction, combining processes of information introduction with processes of classification and generalization, high associativity makes growing pyramid networks an important component of forecasting and diagnosing systems.

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